

ORIGINAL

Mechanism of ST segment depression during exercise tests in patients with liver cirrhosis

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Abstract : Purpose : To our experience, ST segment depression is sometimes detected in an exercise electrocardiogram (ECG) test in patients with liver cirrhosis who have no significant coronary stenosis. In this study, the mechanism of ST segment depression in liver cirrhosis was examined using ^{99m}Tc-methoxy-isobutyl-isonitrile (MIBI) myocardial scintigraphy.

Methods : Six patients with liver cirrhosis (LC group), and 15 normal subjects (N group) were examined. To evaluate the level of myocardial blood flow, a Bull's eye display of myocardial blood flow was performed after dividing the left ventricle into 9 segments. Exercise myocardial scintigraphy with MIBI was performed to obtain the increase in % uptake. Angiographies were performed with a CAG system by inserting a 5 French Judkins catheter via the right femoral artery.

Results : No significant coronary stenosis was found in any of the LC patients. Neither a decrease in MIBI uptake nor defect was observed on Bull's eye images from the LC group. The mean % uptake increase was $61.0 \pm 5.6\%$ in the N group. In the LC group, although neither a decrease in MIBI uptake nor a defect was visually observed on Bull's eye images obtained during exercise, the % uptake increases (mean : $52.5 \pm 5.8\%$) were lower than those of the N group ($p < 0.05$).

Conclusion : These findings suggest that a disorder in coronary flow reserve occurs in liver cirrhosis patients, because the decreased MIBI uptake during exercise is due to the depression of flow-mediated vasodilatation controlled by the endothelium of the coronary artery and the estrogenic digitalis action of blood flow independency. *J. Med. Invest.* 54 : 109-115, February, 2007

Keywords : liver cirrhosis, exercise test, ST-T abnormality, coronary microcirculation, digitalis-like effects

INTRODUCTION

We sometimes experienced that ST segment de-

pression is detected in exercise electrocardiogram (ECG) tests in patients with liver cirrhosis who have no significant coronary stenosis. It is thought that a hormone imbalance and a disorder in the microcirculation of the coronary artery are responsible, but the subject had not been studied the detail until now.

Coronary arterial hemodynamics can be easily detected by myocardial scintigraphy, and not only coro-

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nary artery stenosis but the evaluation of the coronary microcirculation is possible (1). Moreover, coronary arterial flow reserve can be predicted by quantitatively evaluating the level of accumulation of myocardial radioisotope during exercise and at rest (2).

In the present study, the mechanism of ST segment depression in liver cirrhosis was examined using ^{99m}Tc -methoxy-isobutyl-isonitrile (MIBI) myocardial scintigraphy from the viewpoint of microvascular coronary circulation.

METHODS

1) Subjects (Table 1)

Six patients with liver cirrhosis, and age-matched 15 normal subjects were examined. The subjects were 15 healthy male adults (N group; mean age: 60.3 ± 9.8 years) and 6 HCV antibody-positive male patients with liver cirrhosis (LC group; mean age: 61.4 ± 8.6 years). The N group subjects were evaluated as being clinically healthy, based on normal physical findings, a resting blood pressure of 140/90 mmHg or less, and the absence of abnormalities in a standard 12-lead ECG, chest X-ray, urinalysis, and blood biochemistry findings, with no history of cardiopulmonary disease.

In the LC group, the etiology of cirrhosis was a chronic HCV infection in all patients. Patients with alcoholic or hepatitis B-related liver cirrhosis were excluded from the study. The diagnosis of liver cirrhosis was made based on patient history, a physical examination, biochemical blood tests, coagulation function tests, upper gastrointestinal endoscopy, abdominal ultrasonography, and a liver biopsy. Patients in whom esophageal varices were demonstrated by upper gastrointestinal endoscopy, and in whom a reduction in liver size, irregularity of the liver surface, and the presence of splenomegaly were confirmed by abdominal ultrasonography, were selected as subjects. Moreover, all patients of the LC group showed a ST-T abnormality in treadmill stress

ECG. However, patients with abnormal coronary angiographic findings, patients with liver cirrhosis of uncompensated stage and patients who exercise test is impossible were excluded from the present study.

No history of cardiopulmonary disease was evident in the LC group. Chest X-rays, and echocardiograms revealed no abnormalities. The criteria for exclusion were: smokers, systolic blood pressure > 140 mmHg, diastolic blood pressure > 90 mmHg, hyperlipidemia, recent gastrointestinal bleeding, diabetes mellitus, obese (body mass index > 25.0) and neurological disease. In addition, the subjects in the LC group consisted of 4 of Child A patients and 2 with Child B patients (Table 1). These studies were approved by the local Ethics Committee, and the patients provided written, informed consent prior to their participation.

2) Treadmill exercise

The treadmill exercise ECG tests were performed using MAT-2100 (Fukuda Denshi, Tokyo, Japan). A positive ECG response for ischemia was defined as a 1 mm or greater horizontal or downsloping ST depression at 80 msec after the J point during an exercise test. The targeted heart rate [$(220 - \text{age}) \times 90\%$], chest pain, fatigued lower extremities, ST changes on ECG, or pressure-rate product levels were above 25,000. In this study, however, chest symptoms did not appear during exercise test in all subjects in the LC group.

3) Acquisition of myocardial single photon emission computed tomography (SPECT) images (Fig. 1)

The exercise tolerance test was performed using the one-day protocol of the stress-rest method, and the % uptake increase in blood flow during exercise

Table 1 Patients characteristics

	N group	LC group
Age (years)	60.3 ± 9.8	61.4 ± 8.6
T-Bil (mg/dl)	0.7 ± 0.2	1.4 ± 0.3
Alb (mg/dl)	3.9 ± 0.3	3.3 ± 0.4
Child stage		
Child A		4
Child B		2
Child C		0

T-Bil, total bilirubin; Alb, albumin; * $p < 0.05$ vs N group

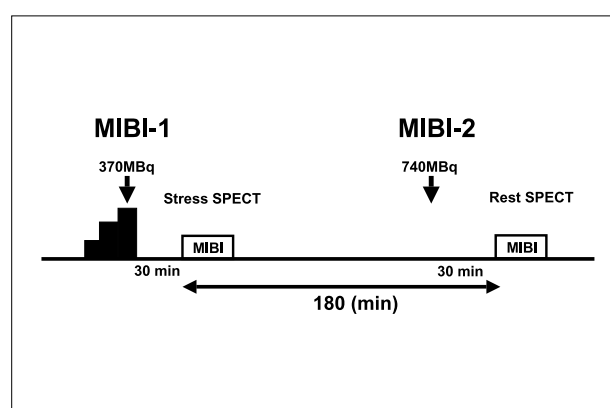


Fig. 1 Acquisition of myocardial SPECT images. MIBI, ^{99m}Tc -methoxy-isobutyl-isonitrile; SPECT, single photon emission computed tomography.

was evaluated by measuring the increase in uptake using MIBI. Using a cycle ergometer, the exercise tolerance test was started at 50 W, and the load intensity was gradually increased in 25 W increments at 3-minute intervals until one of the following conditions was observed as the same protocol of previous treadmill exercise : targeted heart rate [(220-age) \times 90%], chest pain, fatigued lower extremities, ST changes on ECG, or pressure-rate product levels above 25,000. During the maximal load of exercise, 370 MBq of MIBI was administered intravenously, and the exercise was continued for another 90 seconds.

Using a three-headed gamma camera (PRISM 3000, PICKER/Shimadzu Corp., Kyoto, Japan) equipped with a low-energy, high-resolution collimator and an analytical computer (ODYSSEY, Shimadzu), SPECT images were acquired from 72 directions (64×64 matrices/direction for 30 seconds) at 5-degree intervals, which were used as the SPECT images during exercise (stress-SPECT). At 180 minutes after the scan of the stress SPECT, 740 MBq of MIBI was again administered intravenously, and resting SPECT images (rest-SPECT) were acquired 30 minutes later. During exercise and at rest, the radioactivity in the syringe was measured before and after the administration of MIBI using a dose calibrator (CURIEMETER ICG-3, Aloca, Tokyo, Japan), together with the radioactivity in the three-way valve after MIBI administration. The actual dose of MIBI was subsequently calculated based on the radioactivity before and after MIBI administration. The absence of any leakage from the injection site was confirmed by examining the injection site using a gamma camera during SPECT image acquisition.

4) Measurement of % uptake increase in coronary blood flow during exercise

To evaluate the level of myocardial blood flow, a Bull's eye display of myocardial blood flow was performed after dividing the left ventricle into 9 segments ; basal anterior wall, basal septum, basal lateral wall, basal inferior wall, middle anterior wall, middle septum, middle lateral wall, middle inferior wall, and apical region. The radioactivities in these 9 myocardial segments were subsequently measured on a rest-SPECT image and a stress-SPECT image in order to calculate the % uptake increase based on the corrected resting coefficient and the % increase in blood flow using the following equation :

$$\% \text{ uptake increase} = \{ [C1 \times R - (C2 - C1')] / (C2 - C1') \}$$

$\times 100(\%)$

C1 : radioactivity in the myocardium immediately after the initiation of exercise (stress-SPECT image)

C1' : decay correction of C1

C2 : radioactivity in the myocardium immediately after the initiation of exercise (rest-SPECT image)

R : ^{99m}Tc -MIBI dosage at rest / ^{99m}Tc -MIBI dosage at stress

5) Coronary angiography (CAG) and left ventriculography (LVG)

Angiographies were performed with a CAG system (Philips medical system, Tokyo, Japan) by inserting a 5 French Judkins catheter via the right femoral artery. The results were visually evaluated by 3 cardiologists. Based on the severity of stenosis in the proximal region of the main coronary artery, the presence of 75% or more stenosis was defined as a significant stenosis, while the presence of less than 25% stenosis was defined as normal. LVG was performed in the 30-degree right anterior and 60-degree left anterior oblique projections.

6) Statistical Analysis

All values are expressed as the mean \pm standard deviation (SD), and statistical analyses were performed using StatView 5.0 (SAS Institute Inc. USA). Values were compared between the two groups using the unpaired t test. $P < 0.05$ was regarded as significant.

RESULTS

1) Treadmill exercise test

Fig. 2 shows representative examples of ECGs during a treadmill exercise test of a 53 year old male liver cirrhotic patient. In the standard 12-lead ECG at rest (panel a), horizontal or down sloped ST depression was recognized in the I, II, III, aV_F, V₅, V₆ leads.

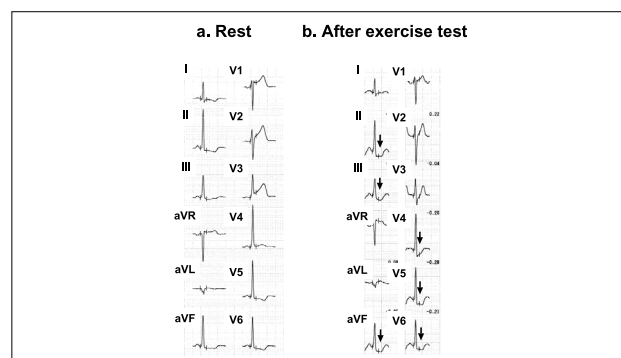


Fig. 2 Representative examples of ECGs during a treadmill exercise test. (53 year old male liver cirrhotic patient)

In the ECG immediately after the exercise test (panel b), a 1 mm greater horizontal and/or downsloping ST depression was recognized in the II, III, aV_F, V₄₋₆ leads, suggesting the presence of myocardial ischemia. In the present study, significant ST-T change in the treadmill exercise test was recognized in all patients of the LC group.

2) CAG and LVG

Fig. 3 shows the CAG and LVG for the same patient of Fig. 2. Neither the left nor right coronary artery showed any significant stenosis, and left ventricular wall motion was normal. No significant coronary stenosis was found in any of the other 5 patients in this study.

3) % uptake increase in blood flow during exercise

Fig. 4 shows a Bull's eye map of stress-SPECT and rest-SPECT images, and % uptake increase for a liver cirrhosis patient. Although neither a decreased MIBI uptake nor a filling defect was visually observed, the % uptake increase in each myocardial segment (48-55%) was lower than that in healthy subjects.

Table 2 shows a comparison of % uptake increases

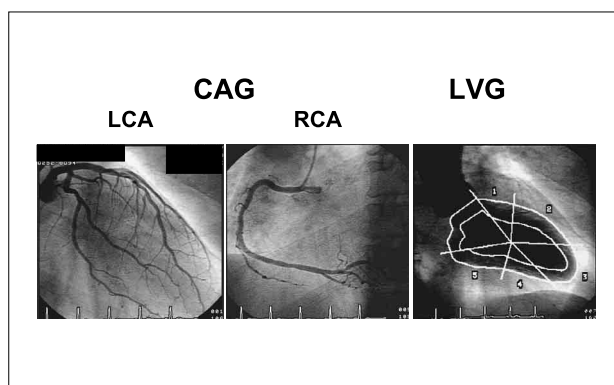


Fig. 3 CAG and LVG for the same patient described in Fig. 2.

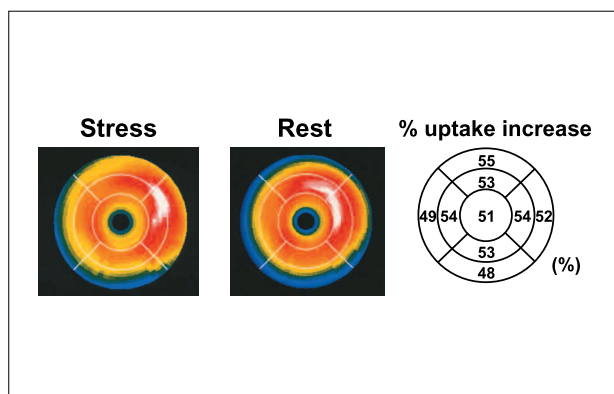


Fig. 4 Bull's eye map of stress-SPECT and rest-SPECT images, and % uptake increase for a liver cirrhosis patient.

Table 2 Comparison of % uptake increases in 9 myocardial segments between the LC and N groups

	LC group	N group	p value
Total	52.8±5.8(%)	61.0±5.6(%)	<0.05
Apical.	48.6±4.4	56.9±5.4	<0.05
Mid. Lat.	58.4±3.9	67.9±7.1	<0.05
Mid. Ant.	51.6±3.9	60.9±3.0	<0.05
Mid. Sept.	45.0±3.6	57.5±3.0	<0.05
Mid. Inf.	56.4±4.3	64.8±7.0	<0.05
Bas. Lat.	53.3±5.4	60.5±6.4	<0.05
Bas. Ant.	46.3±6.0	53.6±7.1	<0.05
Bas. Sept.	54.0±3.9	59.8±4.8	<0.05
Bas. Inf.	60.1±4.1	66.8±4.5	<0.05

Mid. Lat, middle lateral wall ; Mid. Ant, middle anterior wall ; Mid. Sep, middle septal wall ; Mid. Inf, middle inferior wall ; Bas. Lat, basal lateral wall ; Bas. Ant, basal anterior wall ; Bas. Sep, basal septal wall ; Bas. Inf, basal inferior wall ;

in 9 myocardial segments between the LC and N groups. The % uptake increase was significantly lower in the LC group than in the N group in all myocardial segments ($p<0.05$), indicating a decreased coronary flow reserve. However, there were no significant differences in the % uptake increases among the myocardial segments in liver patients. In the N group, although the % uptake increase in the middle lateral wall significantly differed from that in the basal anterior wall, there were no significant differences in % uptake increases among other myocardial segments.

DISCUSSION

Though depressed ST is found in exercise ECG tests in liver cirrhosis, some patients show no significant evidence for coronary artery stenosis. In the present study, the mechanisms of ST depression in exercise ECG tests were investigated using ^{99m}Tc -MIBI stress myocardial scintigraphy in liver cirrhosis. It is possible that the decreased ^{99m}Tc -MIBI uptake during exercise is due to the depression of flow-mediated vasodilatation controlled by the endothelium of the coronary artery, and a coronary endothelium dysfunction typically exists in patients with cirrhosis. The findings indicate that a disorder in coronary flow reserve occurs in liver cirrhosis patients without any significant coronary stenosis.

1) Coronary circulation and myocardial scintigraphy

Since a decreased isotope uptake is visually ob-

served in the myocardium perfused by flow mediated vasodilatation during exercise, the % uptake increase may be lower in patients with coronary microcirculation disorders. In the present study, the % increase in blood flow decreased significantly during exercise in cirrhotic patients, even in myocardial segments that did not show a visual decrease in perfusion during myocardial SPECT using MIBI.

Coronary arterial hemodynamics can be readily evaluated by myocardial scintigraphy, which facilitate the diagnosis of significant coronary arterial stenosis and the evaluation of coronary arterial microvascular disorders to be evaluated (2-8). In recent years, several studies have reported that coronary arterial flow reserve can be predicted by quantitatively evaluating the level of myocardial radioisotope that accumulates during exercise and at rest using ^{99m}Tc -tetrofosmin-myocardial SPECT, which also facilitated measurement of the coronary arterial flow reserve (1, 2).

Nagamine, *et al.* (9) reported that conjugated estrogen induces sludging and stasis in the microcirculation, of which is the magnitude approximately proportional to the concentration and dose. However, many studies (10, 11) have indicated that estrogen acts protectively for vascular endothelium functions. Therefore, it is difficult to attribute the decrease in % uptake increase from the viewpoint of estrogen.

2) Effects of microcirculation and action potential by estrogen

A number of reports have appeared that indicate sex steroid hormones are involved the false positive of an exercise ECG test (12-18). Kanda, *et al.* (19) reported on the mechanism of coronary artery spasms, and that the gene of the smooth muscle of the human coronary artery can be activated by estrogen and that this activation was preventable by the administration of progesterone. It is possible that the decreased ^{99m}Tc -MIBI uptake during exercise is due to the depression of flow-mediated vasodilatation, which is controlled by the endothelium of the coronary artery, and a coronary endothelium dysfunction exists in patients with cirrhosis.

On the other hand, there is clinical condition called cardiac syndrome X in pre-menopausal women in which significant coronary arterial stenosis is absent (20). It has been hypothesized that an estrogen deficiency may play a major role in the pathogenesis associated with this condition. Minshall, *et al.* (21) hypothesize that vascular hyperreactivity, which

may be a critical factor in the increased incidence of coronary artery vasospasm and ischemic heart disease in postmenopausal women, can be normalized by estradiol and/or progesterone through a direct action on coronary artery vascular muscle cells.

Holdright, *et al.* (22) however, reported that conventionally used hormone replacement therapy had no acute effect on a treadmill performance in the postmenopausal women with coronary artery disease. Bakhari, *et al.* (23) emphasized the importance of progesterone, and suggested that estrogen increases the false positive rate of stress ECG, and this decreased specificity can be countered by the co-administration of progesterone. Therefore, it is possible that an estrogen and progesterone imbalance causes the coronary artery circulation disorder.

Tanabe, *et al.* (24) reported on the effects of estrogen on action potential and membrane currents. They suggested that 17beta-estradiol prolonged the action potential duration mainly by inhibiting the outward K^+ current and the slowly activating component and prolonged the QT interval. This electrophysiological effect of estrogen might be related to the ST change in an ECG.

3) Liver cirrhosis and arteriosclerosis

In the present study, cirrhotic patients with significant coronary stenosis were not investigated, but ^{99m}Tc -MIBI myocardial scintigraphy could be clinically useful, because it facilitate both the diagnosis of significant coronary arterial stenoses and the evaluation of coronary arterial microvascular disorders.

It has been reported that liver cirrhosis developed with difficulty in cases of arteriosclerosis such as coronary artery disease (25-28), but arteriosclerosis was recently found to be complicated with a high frequency in this disease, in a study of pulse wave velocity (PWV) which facilitated the objective evaluation of the severity of arteriosclerosis (29, 30).

It has been also suggested recently that arteriosclerosis is closely associated with inflammation (31). Even in patients with viral hepatitis, vascular wall inflammation caused by chronic infections may play an important role in the development of arteriosclerosis. In patients with hepatitis C, positivity for the HCV core protein is an independent risk factor for plaque formation in the carotid artery (32). Furthermore, increased levels of high-sensitivity CRP in LC patients suggests the presence of arterial wall sclerosis induced by micro-inflammatory reactions (31).

4) Analogy of chemical constitution between steroid sex hormones and digitalis

Sundqvist, et al. and Jaeschke et al. reported that digoxin has influence on the exercise ECG (33-35). In male liver cirrhosis patients, and the possibility that increased estrogen levels caused an ST-T change in resting and exercise ECG, similar to digitalis. The findings of this study suggest that the causes of ST depression during exercise on ECG test in cirrhotic patients are a decrease in coronary blood flow increase response and the estrogenic digitalis action of blood flow independency.

In conclusion, these findings suggest that a disorder in coronary flow reserve occurs in liver cirrhosis patients, and that estrogen might decrease the coronary microcirculation and also have digitalis-like effects.

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